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TECHNOLOGY TRANSITION AND TRANSFER STRATEGY

May 1995
Prepared by:

The Technology Transition Strategy Panel Established by the Aeronautical Systems Center (ASC) and the National Security Industrial Association (NSIA) sponsored Engineering/Manufacturing Day

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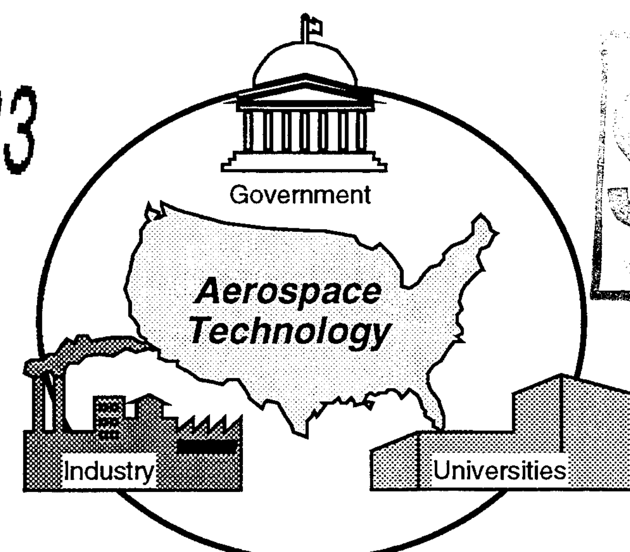

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13. ABSTRACT *(Maximum 200 words)*

A PROPOSAL FOR A GOVERNMENT/INDUSTRY PANEL TO FORMULATE A TECHNOLOGY TRANSITION STRATEGY WAS ESTABLISHED BY THE AERONAUTICAL SYSTEMS CENTER (ASC) AND THE NATIONAL SECURITY INDUSTRIAL ASSOCIATION (NSIA) SPONSORED ENGINEERING/MANUFACTURING DAYS. THE PANEL WAS CHAIRED BY MR. O. LESTER SMITHERS, DEPUTY DIRECTOR, WRIGHT LABORATORY, AND MR. ERNEST C. BRYAN, SENIOR VICE PRESIDENT, GOVERNMENT ENGINEERING, UNITED TECHNOLOGIES, PRATT & WHITNEY. THE TECHNOLOGY TRANSITION STRATEGY PANEL'S MISSION WAS TO **FORMULATE A TECHNOLOGY TRANSITION AND TRANSFER STRATEGY FOR GOVERNMENT, INDUSTRY, AND UNIVERSITIES TO MAINTAIN THE UNITED STATES' PREEMINENT AEROSPACE TECHNOLOGY BASE IN A DECLINING DoD BUDGET ERA.** THE DEVELOPMENT AND TRANSITION OF TECHNOLOGY FOR WEAPON SYSTEMS IS A JOINT EFFORT BETWEEN GOVERNMENT, INDUSTRY, AND UNIVERSITIES. FROM BASIC RESEARCH THROUGH WEAPON SYSTEM PRODUCTION OR MODERNIZATION, THIS PARTNERSHIP IS A CRITICAL ELEMENT FOR SUCCESSFUL TECHNOLOGY TRANSITION. THE OBJECTIVE OF THE TECHNOLOGY TRANSITION AND TRANSFER STRATEGY IS TO BUILD UPON THESE PARTNERSHIPS.

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Table of Contents

Page

List of Figures

1.0 Executive Overview

The development and transition of technology for weapon systems (Fig 1.1) requires a joint effort between government, industry, and universities. From basic research through weapon system production or modernization, this partnership is a critical element for successful technology transition. The Department of Defense (DOD) laboratories' primary role is to orchestrate the development of technology for transition to new or existing weapon systems. While industry plays a major role in technology development through Contracted Research and Development (CRAD) efforts with the DOD laboratories and its own directed Independent Research and Development (IRAD), industry's primary role is to transition technology in the building of new or upgrading existing weapon systems. The role of the universities is to conduct basic and applied research, to educate students in the fundamentals of science and engineering at all levels, and to

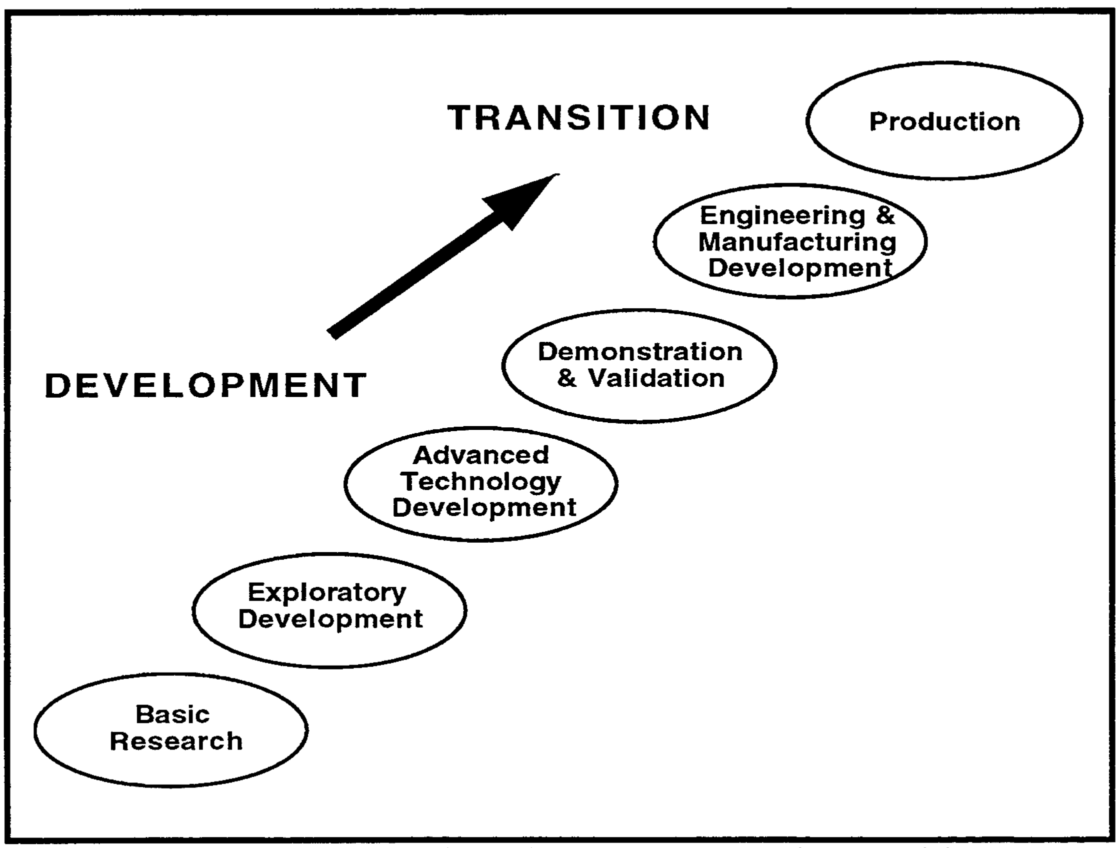

Figure 1.1 Technology Development and Transition

facilitate transition of university-developed technology to industry. The objective of the Technology Transition and Transfer Strategy is to build upon these partnerships.

The Technology Transition Strategy Panel's mission is to ***formulate a technology transition and transfer strategy for government, industry, and universities to maintain the United States' preeminent aerospace technology base in a declining DoD budget era.*** The recommended strategy is modeled after successful initiatives in specific areas of aerospace technology development, and proposes the establishment of Steering Committees for the technical disciplines of <u>airframe</u>, <u>avionics</u>, and <u>propulsion</u>. These three Steering Committees should have broad, high level membership (recognized national leaders) from government and industry. Each Steering Committee would identify national aerospace goals that have the objective of maintaining United States' leadership in both military and commercial aerospace. Each Committee would also formulate long-range (25 years), technically challenging Science & Technology initiatives with 2-3 year achievement milestones to measure progress towards meeting these national aerospace goals.

Air Force laboratory planners would develop an investment strategy based on inputs from the Air Force Materiel Command Technology Master Process (TMP) supplemented with the long-range plans for achieving national goals and initiatives recommended by the Steering Committees. The supplement of the TMP with Steering Committees inputs promotes a partnership between government, universities, and industry that provides synergism between all funding sources. This synergism is critical in the formulation of long-range research and development technology base plans for basic research, exploratory development, and advanced technology development programs. Exploratory development efforts would pursue high risk, high-payoff options that include a balanced level of manufacturing process modeling and development. Advanced technology development programs would be risk reducing critical experiments that demonstrate technical feasibility of both product and manufacturing process capabilities at the component level in a laboratory environment. Advanced technology development programs would consist of low cost *incremental technology demonstrations* (laboratory simulations, ground demonstrations, etc.) that would provide continuous opportunities for technology maturation. Matured technologies from these incremental technology demonstrations would be transitioned to military applications and/or transferred to commercial applications, while those technologies that require further risk reduction would be matured through strategically planned *advanced environmental ground*

demonstrations or systems integration *flight demonstrations* in commercial or military derivative vehicles. Another key element of this strategy will be the encouragement, rather than avoidance, of inter-company and industry-university cooperation in developing new technologies so that the effectiveness of the tax dollar is increased.

1.1 Recommendations

The Panel recommends that the Air Force and industry should: (1) facilitate the formation of three prototype Steering Committees; (2) promote the incorporation of this strategy as a supplement to the existing Air Force Materiel Command (AFMC) Technology Master Process.

> *Over the past half century, technical advances have been responsible for most of the productivity growth in the United States. At the same time, the influence of the federal government on , and the reaction to, technological change has largely been through support for basic science and mission-oriented research and development -- primarily defense technology.*[1]

The defense budget alone cannot support this nation's aerospace technology base. The cultural change to share this leadership with industry and universities requires mutual trust and joint planning. The implementation of this strategy would provide a significant step towards this change and could be a pivotal initiative at preserving one of the few remaining high technology industries where the United States enjoys world leadership.

2.0 Background

A proposal for a government/industry Panel to formulate a Technology Transition Strategy was one of four government/industry working teams proposed to address critical issues identified during the 16-17 April 1992 ASC Engineering/Manufacturing Day meeting at the U.S. Air Force's Aeronautical Systems Center, Wright-Patterson AFB, Ohio. Other teams were identified to address the following issues: (1) Technology Strategy for a Shrinking Industrial Base; (2) Review of the Draft Systems Engineering/Configuration Management Process (SE/CM); (3) Incorporation of Commercial vs. Military Quality Standards. The Technology Transition Strategy Panel membership was established (Fig 2.1) and the Panel's kick-off meeting was held on 3 Feb 1993.

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Figure 2.1 Technology Transition Strategy Panel Members

3.0 Approach

The Panel reviewed the Wright Laboratory technology transition process, including the Air Force Materiel Command (AFMC) Technology Master Process as examples of existing military processes. This diverse group discussed many different issues from which to formulate a strategy including: (1) recommendations for technology transition from military to commercial and vice-versa; (2) recommendations for technology transition to product; (3) increased technology cooperation between USA companies, government agencies, and universities; (4) technology transfer to foreign industry.

The following definitions for technology transition and transfer were agreed upon to focus strategy development: ***Technology transition*** is the movement of defense developed technologies from the government, industry, and universities to military system applications, while ***technology transfer*** is the movement of defense developed technologies from the military to commercial applications or nondefense developed technologies from commercial to military applications. The present and future impact of reduced DoD budgets requires the development of a joint (government, industry, universities) strategy that includes both technology transition and transfer.

The Panel's derived mission statement: ***Formulate a technology transition and transfer strategy for government, industry, and universities to maintain the United States' preeminent aerospace technology base in a declining DoD budget era,*** responds to President Clinton's technology policy which is aimed at solving the twin problems of national security and economic competitiveness. *This policy shifts federal R&D funding from 60/40 defense/civilian split to 50/50 (transfer of $7.6 billion per year out of DoD/DoE).*[2] The 1993 Defense Conversion Appropriation (approx. $1.8B) has steered particular focus on dual-use capabilities for national defense and industrial base. *The fiscal year 1993 Title IV appropriations for Technology Reinvestment Project (approx. $472M) addresses initiatives on dual-use technology, industrial/regional partnerships, and development of technology and industrial base.*[3] The Panel agreed that a "front end" strategic plan to support these initiatives is required for an effective technology transition and transfer strategy.

3.1 Technology Transition and Transfer "Hurdles"

During initial brainstorming sessions, the Panel identified "hurdles" that were perceived to interfere with the present practices of accomplishing technology transition and transfer. After review of each of the hurdles, the following list was established. This list was used to derive the operating guidelines within the Technology Transition and Transfer Strategy.

1. Inadequate communication of technology needs for strategic planning
2. Lack of "technology pull" from end-item user
3. Use of commercial vs. DoD standards, practices & regulations
4. Lack of joint risk management on the part of both government and industry
5. Inability to adapt technology to the "Lean Manufacturing" Strategy
6. Cost impact of technology makes it unaffordable
7. Uncertainty of DoD Science & Technology budget

1. **Inadequate communication of technology needs for strategic planning** - More effective communication between government, industry, and universities would provide invaluable feedback for optimal investment. The following example illustrates the value of a communication network between an Air Force Major Command and industry. Headquarters Air Combat Command (HQ ACC) currently hosts Independent Research and Development (IR&D) technical information interchange meetings to facilitate face-to-face interactions between users and technical managers from both industry and government. Companies are provided insight to government plans and requirements while the user is briefed by company representatives on applicable IR&D. Endorsed IR&D technologies are reflected in Mission Area Plans (MAPs) created by the user. MAPs provide a critical link between requirement, programming, laboratory S&T, and IR&D processes. Following each meeting written feedback is exchanged between both parties. These interchanges have been well received by both industry and government participants. However, this process is done only with individual companies, while industry jointly does not benefit from the total IR&D picture due to proprietary constraints. Also, this process is only known to be used by HQ ACC and no similar review is exercised by the other Air Force Major Commands. A modified application of this process to include cross communication between companies on their IR&D work could reduce IR&D duplication between companies while providing a critical link between IR&D process and the AFMC Technology Master Process (TMP)

within the overall "Operational Requirements and Modernization Planning Process" (Fig 3.1.1). *The TMP is an end-to-end process for technology development, transition, and application/insertion by insuring (1) all needs for both internal and external AFMC customers are identified and prioritized, (2) dollar-constrained technology projects are formulated in a highly integrated manner with full participation by all stakeholders to satisfy those needs, (3) any technologies flowing into AFMC centers for application/insertion are validated to reduce risk during the acquisition cycle.*[4]

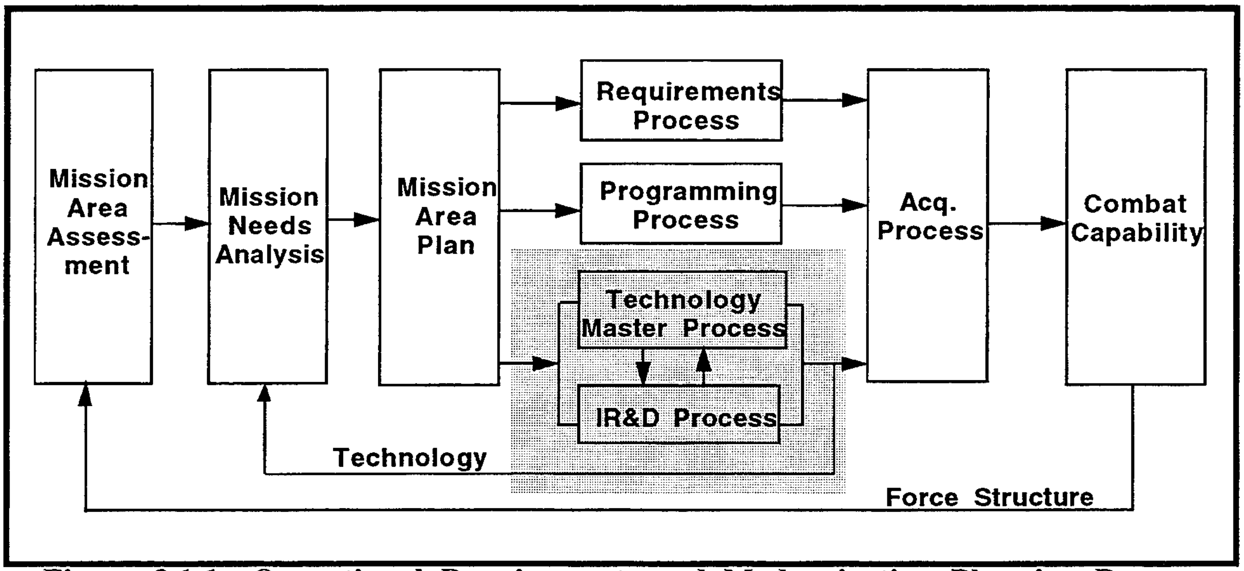

Figure 3.1.1 Operational Requirements and Modernization Planning Process

2. **Lack of "technology pull" from end-item user -** The Panel reviewed examples of technology incorporation driven by user need (technology pull) versus technology incorporation that is not driven by user deficiency (technology push) timelines for propulsion related technologies (Fig 3.1.2). These particular examples illustrated that technology push programs typically take much longer and are less likely to reach any level of production. An example of a technology push effort is the Pitch/Yaw Balanced Beam Nozzle. This effort was an invention that did not response to any near-term deficiency of the user. This technology has been demonstrated to provide increased fighter aircraft agility, but without user pull, getting this technology into production is difficult and may never happen. Conversely, technology pull efforts such as the hollow fan blade showed near-term payoff to a product and fulfilled a timely solution to a user

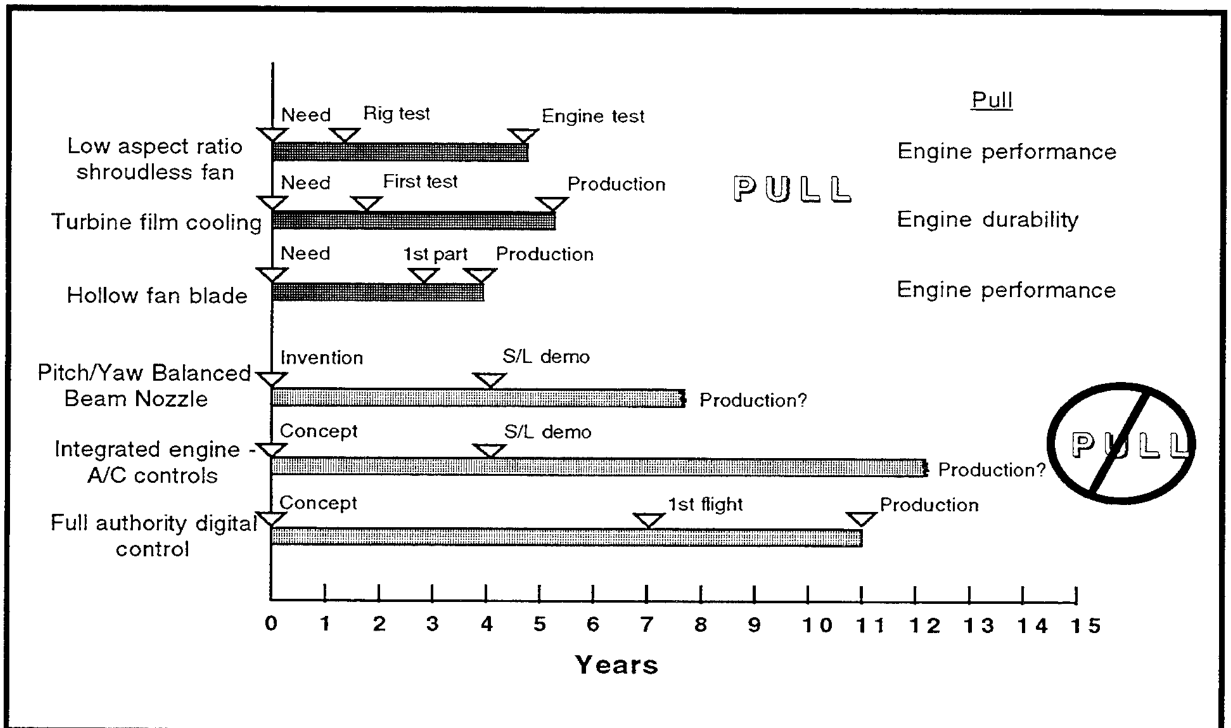

Figure 3.1.2 Propulsion Technology Incorporation Driven By User "Pull"

deficiency of insufficient engine performance. User pull supported funding for near-term application and this technology reached production in 4 years. Often the user's focus on deficiencies is too near-term because his mission is being driven by ever-changing global situations. Technology push programs can provide mid and far-term focus if they address technology maturity including risk reduction and reasonable costs for the class of targeted weapon system. Both technology push and technology pull are required for a complete technology planning process that includes a balance of short-, mid-, and far-term investments.

3. **Use of commercial vs. DoD standards, practices & regulations -** The Panel examined examples depicting the differences between commercial and military practices. Commercial and military engine markets have different philosophies when considering up-front and life-cycle costs; While both costs are evaluated in each market, the military engine market is primarily driven with life-cycle costs while the commercial engine market is primarily driven with up-front costs and arriving at the market first. The military market is not driven by the commercial

competitive forces until a threat emerges. As shown in figure 3.1.3 Engine Program Comparison competitive market conditions dictate that commercial programs make effective use of leadtime reductions to improve time-to-market. Generally, timelines of military engines are longer to reach

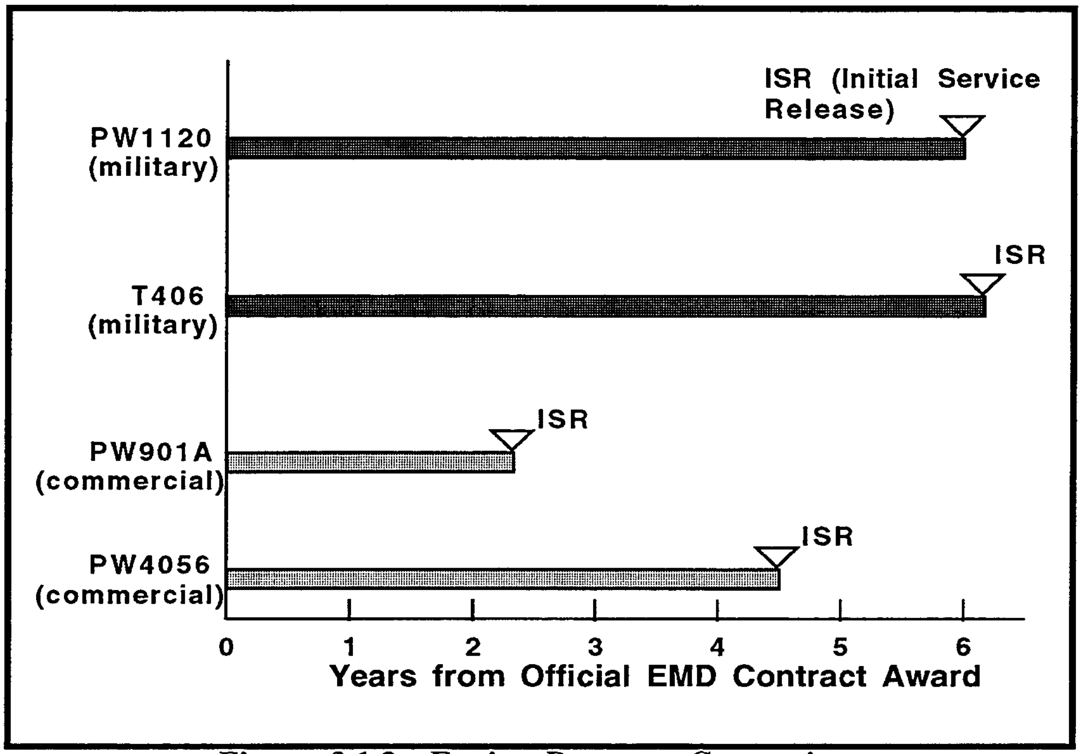

Figure 3.1.3 Engine Program Comparison

initial service release versus those of commercial engines. Even though the end-use of military and commercial engines are unique, subassemblies and components that make up these engines can be very comparable devices. This generic characteristic can be used to take advantage of dual-use manufacturing along with more efficient approaches to meeting both commercial and DoD standards and regulations.

4. **Lack of joint risk management on part of both government and industry** - Effective technology transition is delayed because risk management and affordability have not been adequately address during technology development. By not adequately addressing these key issues, risk avoidance becomes prevalent. Risk avoidance generates excessive conservatism in the

decision making process, resulting in biased decisions. The risk of failure and lack of timely decisions delay innovation.

> *Technology base research must pursue high-risk, high-payoff options. An atmosphere which inhibits risk-taking will result in a research program which has a short-term focus. This compromises the ability of the program, over time, to identify and pursue major new technological opportunities.*[5]

Risk management has become ever more important in a reduced DoD budget environment. Program offices will no longer have the resources to mature technology for application on a particular weapon system that has been developed through S&T resources. The S&T community must strive to reduce technical risk for successful technology transition.

> *Risk Management is a tool Program Management, Engineering, Customer Support and Manufacturing must use to highlight technical risk and provide a disciplined approach to risk reduction. This tool will help in allocating resources more effectively by providing a means to match resources with risk levels. Technical risk is defined as the degree of uncertainty about the ability of a system or process to achieve its stated design/manufacturing/support objectives within the program's cost and schedule constraints.*[6]

5. **Inability to adapt technology to the "Lean Manufacturing" Strategy** - *Lean Manufacturing is a dynamic process of change driven by a systematic set of principles, methods and practices aimed at improving firm and industrial performance.*[7] Lean Manufacturing addresses efficiencies in the entire factory enterprise, including interaction between design and manufacturing. The fundamental technological processes to address this interaction between design and manufacturing for the aerospace industry have not been matured. An example is the existing void in tools for manufacturing process modeling. The cost and risk associated with the Engineering Manufacturing Development (EMD) phase of acquisition programs could be reduced by comprehensive modeling capability that would limit the number of "trial and error" procedures that typically occur on the manufacturing floor. Lean manufacturing concepts, as applied to technology development and transition emphasize the need for balanced product and process

development and the ability to predict, within statistical confidence intervals, the producibility of early technology designs. A strategic plan to develop and refine manufacturing process modeling is required before the aerospace industry can successfully apply the Lean Manufacturing concepts to high technology weapon systems.

6. **Cost impact of technology makes it unaffordable** - *A technology is considered affordable if it meets the customer's requirements, is within the customer's budget, and has the best value among available alternatives.*[8] The tools required to achieve this affordability goal, by managing cost and risk, are far from being realized. Also, expertise and training for engineers and managers to understand the factors that are critical to the costs of acquiring and owning weapon systems simply do not exist to the level required to meet the affordability goal. The ability to use affordability as a design parameter is practically nonexistent in aerospace Science &Technology (S&T). Much of the aerospace industry still uses the ancient cost analysis parameter dollars per pound due to the lack of better tools. New standardized tools are required to help engineers and managers address cost issues including producibility, reliability, maintainability, and supportability during the technology development process. *Numerous studies have demonstrated that 85% of weapon system development cost is locked in during the initial 15% of the effort.*[9] The reoccurring policy of lengthening the schedules of new weapon system programs along with reduced numbers of total systems being acquired is evidence that we are not meeting the customer's budget. We must improve and standardized the S&T tools to achieve affordability in the face of future declining DoD resources.

7. **Uncertainty of DoD Science & Technology budget** - The DoD laboratory infrastructure was reduced by about $200 million for fiscal 1994. Similar reductions are planned for fiscal 1995 and beyond to downsize the laboratories. The laboratories must plan to make the most of the limited future resources. Key areas that the laboratories could work include: (1) streamline the laboratory acquisition process; (2) more emphasis on the development of process modeling tools to be used for both 6.2 exploratory development and 6.3A advanced technology development; and (3) use of Integrated Product and Process Development (IPPD) in laboratory 6.3A advanced technology development. With a truly integrated product team, the laboratories could provide significant technology risk reduction prior to EMD and production. This may result

in more expensive S&T, but will payoff in shortening the timeline of future acquisition programs while still giving the aerospace industry valuable Research and Development business.

3.2 Case Studies

The Panel discussed existing initiatives that could be used as case studies from

	MIMIC	IHPTET	MASAP
Goals	Microwave & MM Wave subsystems (affordable, available, dual-use)	Gas turbine engine research & development (performance driven)	Develop & characterize materials; applications; producibility
Structure	4 Phase / 8 year; program definition; process & product component dev; demos	3 Phased / 20 year; tech base R&D; process & product component dev; demos	46 months;material concentration;shared results;
Leadership	Industry Executive Steering Committee; ARPA Program Mgmt	Government & Industry Steering Committee	Industry Executive Steering Group; NASP JPO Mgmt
Teaming	IPD - industry	IPD - government / industry	IPD - industry
Funding	$550M - DoD Services, ARPA	$6B - DoD Services / NASA / Industry	$136 M - NASP JPO; contractor IR&D

Figure 3.2.1 Case Study Comparison

which to formulate a strategy. The Microwave and Millimeter Wave Monolithic Integrated Circuit (MIMIC), the Integrated High Performance Turbine Engine Technology (IHPTET), and the National Aerospace Plane Materials & Structures Augmentation Program (MASAP) were identified as examples of ongoing technology development efforts in the functional disciplines of avionics, engines, and airframes, respectively. Each effort was examined in terms of goals, structure, leadership, teaming, and funding (Fig 3.2.1). Important characteristics of these three initiatives that were noted by the panel included: (1) quantifiable and technically challenging goals; (2) long-term commitment by both industry and government; (3) joint steering committees providing leadership; (4) shared resources by industry and government; (5) program goals differed in attention towards cost and producibility.

The **MIMIC** effort is a 4-phase, 8-year program (FY87-FY95) funded by the Electronic Systems Technology Office of the Advanced Research Projects Agency (ARPA/ESTO). The program was managed by ARPA, Air Force (WL/EL), Army (ARL/AMSRL), and Navy (NASC & NRL). The objective of the program is to develop microwave and millimeter-wave monolithic integrated circuit chips that are affordable, available, and broadly applicable to a large number of military systems. Work is focused on MIMIC computer-aided design, gallium arsenide (GaAs) materials growth and characterization, chip fabrication yield improvement, high speed on-wafer testing, and demonstration of MIMIC technology in subsystem brassboards. MIMICs are being built and transitioned into a broad range of military radar, electronic warfare, communications, and smart weapon systems. For example in the Air Force, MIMICs are being used in AMRAAM, LANTIRN, ALQ-135, F-22 (radar & EW), and F-15 & F-16 receivers. MIMICs are also finding use in commercial applications such as cellular telephone, wireless communications, direct broadcast satellite, aviation, and security systems. The MIMIC program emphasizes the use of IPPD teams across industry that allows the best experts from each company to combine their talents in finding technological solutions. The primary contractors were responsible for forming and leading the IPPD teams and establishing data exchange agreements to share proprietary data within their team. This encouraged continued participation by all members of each team in order to stay abreast of the technology developments throughout the program. The material/technology development and manufacturing phases of the program each have interim demonstrations planned to ensure technology maturation. This program is an excellent example of technology transition and transfer through successful teamwork between industrial competitors, with mutual benefit for all its members.

The **IHPTET** initiative is a revolutionary approach to coordinate engine development (materials, aerothermodynamics, structural design, advanced computational methods) that ensures innovation to realize the full potential of gas turbine engines. This initiative is funded by industry(52%), AF(32%), Navy(6%), NASA(5%), Army(4%), and ARPA(1%) and has phased goals that address 3 classes of gas turbine engine applications (military missiles, military and civilian aircraft). This approach reduces risk through sequential time-phased engine demonstrators and allows technology insertion at earliest opportunity. IHPTET management structure features a joint industry and government steering committee that reviews progress, plans, and addresses issues. Once the technology goals of the initiative were focused, technology investments were directed which, in-turn, aided strategic planning by all team members. The technology goals are

performance driven (double the thrust-to-weight ratio) for military engine applications with commercial market benefits. Without military application as the driver, it is unlikely that the commercial market alone would have set such high risk goals.

The NASP **MASAP** was derived to face major challenges in the area of materials characterization. This was a 46-month effort that started in March 1988 and was funded by the NASP Joint Program Office (JPO) and contractor IR&D. A materials consortium was formed (via contract option of associate contractors) and managed by the NASP JPO and a industry executive steering committee. Both completed and current IR&D were shared by all team members although, it was up to each company to determine the amount IR&D information they volunteered. The consortium focused on producible processes with lower costs, smaller/less costly vehicle design, and the establishment of an advanced material supplier base. All program goals were managed against technology transfer and supported by published cases of dual-use technology. The consortium approach proved a very successful way to manage this particular technology program. MASAP was critical in establishing material and structural designs that met the vehicle requirements, developed a broad industrial base, and maximized the return on the investment of resources for the NASP program.

3.3 Strategy Focus

The Panel's review of the 3 case studies focused the strategy formulation towards an advocacy of technology demonstrations in areas that would create high technology competitiveness and provide national focus. The Panel recognized that flight demonstrations and/or advanced environmental ground demonstrations (e.g., roof house test of radar, vibration and temperature test of avionics, etc.) are the ultimate process to show advantages of technologies, demonstrate systems integration, and provide operational validation, all necessary to get advocacy from both military and commercial customers. Each technology focus area would eventually require these more expensive demonstrations, but not without being preceded by several incremental technology demonstrations that could mature some technologies sufficiently for military and commercial applications. This proposed focus on which to formulate a Technology Transition and Transfer Strategy was briefed by the Panel's cochair, Mr. Ernest Bryan, at the Engineering/Manufacturing Day meeting, 21 April 1993, and received endorsement.

4.0 Strategy

The Technology Transition Strategy Panel's goal is to provide government, industry, and universities with a baseline strategy (Fig. 4.0.1) for maintaining United States leadership in aerospace technology for military and commercial products. Our strategy is modeled after successful initiatives in specific areas of aerospace, and proposes the establishment of **steering committees** for the technical disciplines of **airframe**, **avionics**, and **propulsion**. These three steering committees should have broad, high level membership (recognized national leaders) from government and industry. Each steering committee would have 1 year to:

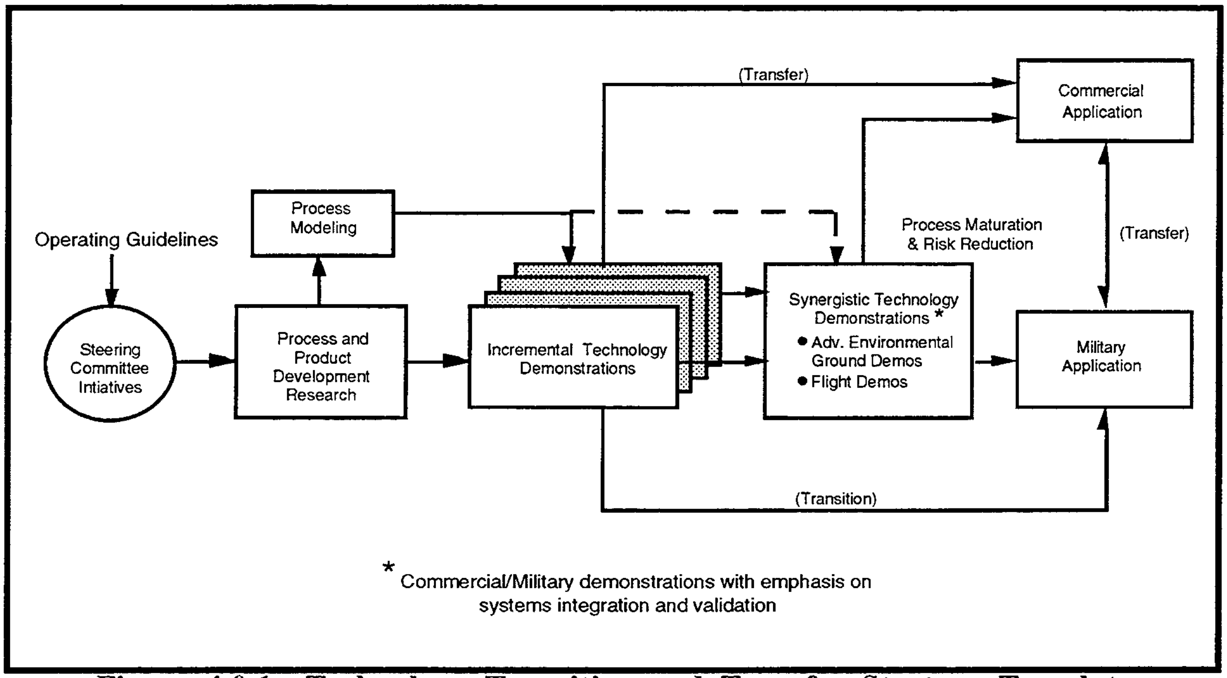

Figure 4.0.1 Technology Transition and Transfer Strategy Template

a. Identify national aerospace goals that have the objective of maintaining United States leadership in both military and commercial aerospace. These national goals will include affordability, performance, producibility, maintainability, and international competitiveness as figures of merit.

b. Formulate long range (25 years), technically challenging Science & Technology initiatives to meet the identified goals. These initiatives will promote product and manufacturing process technology development. Air Force laboratory planners could use these initiatives to formulate research and development technology base plans for the establishment and execution of basic research, exploratory development, and advanced technology development programs.

This proposed strategy would augment the program execution phase of the Air Force Materiel Command (AFMC) Technology Master Process (TMP) (Fig 4.0.2) which is used to define and execute the Science & Technology program in the Air Force Laboratories.

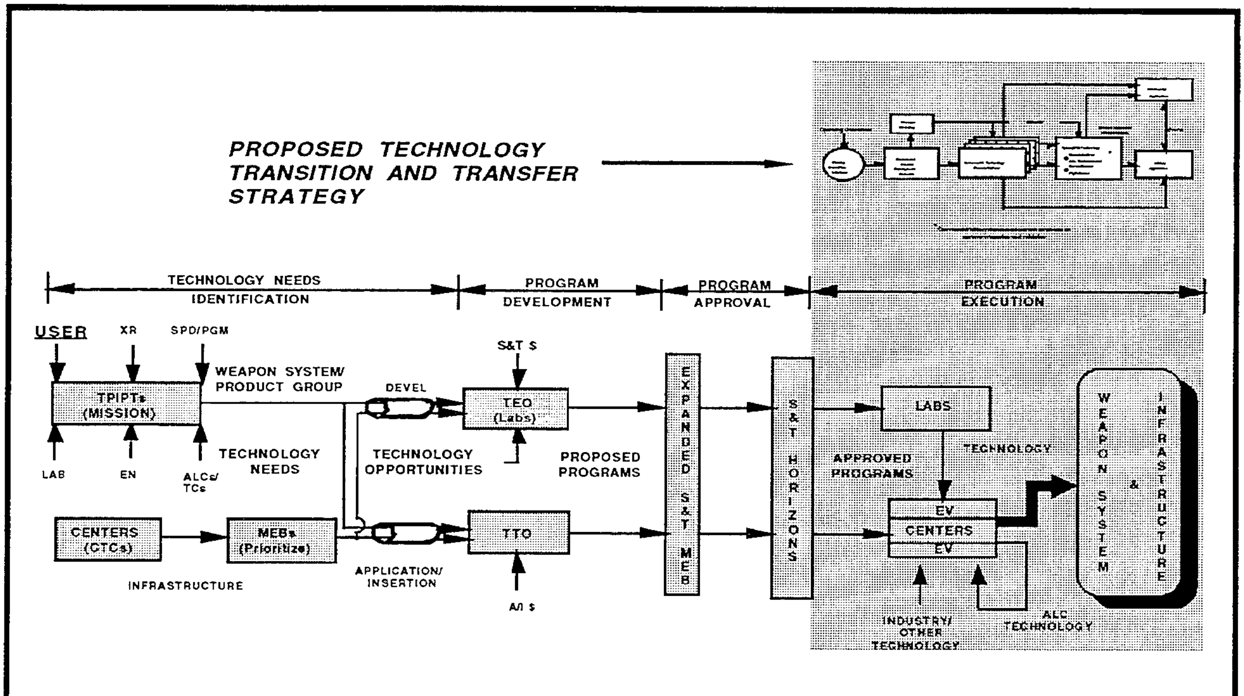

Figure 4.0.2 Strategy Augmented to AFMC Technology Master Process

The TMP has four phases: Technology Needs Identification, Program Development, Program Approval, and Program Execution.

Phase 1: Technology Needs Identification - Mission capabilities that are not being fulfilled (deficiencies) are identified by the MAJCOMs and documented in their MAPs. *Weapon system deficiencies* are investigated by the mission oriented Technical Planning Integrated Product Teams (TPIPTs) that have been established throughout the product centers in AFMC. Each TPIPT is a multidisciplinary team working together towards a common goal of identifying technology needs to meet customer deficiencies. *Infrastructure deficiencies* are investigated by the Center Technology Councils (CTCs) and, like the TPIPTs, the CTCs identify technology needs. The Steering Committees goals and initiatives would provide a national perspective on technology needs and goals with a longer term projection. Both sources would provide a critical balance in formulating the direction of technology development with reduced risk of valuable DoD resources.

Phase 2: Program Development - Technology needs provide critical input into the Air Force Laboratories' Science & Technology planning process. Air Force laboratories planners would balance the initiatives identified by the Steering Committees with weapon system and infrastructure technology development needs to formulate research and development technology base plans for the establishment and execution of basic research, exploratory development, and advanced technology development programs to provide potential technology solutions. These potential technology solutions would be coordinated through the TPIPTs and CTCs to ensure that each technology need is understood along with its potential solution(s).

Phase 3: Program Approval - The proposed laboratory programs are presented to Air Force officials for approval through two review processes: Expanded S&T Mission Element Board (MEB) and S&T Horizons. The Expanded S&T MEB consist of senior MAJCOM requirements representatives, AFMC MEB chairpersons, and Functional Element Board Chairpersons. They are responsible for review and approval of a portfolio of technology projects that constitute the AFMC Technology Investment Plan. *The S&T Horizons consist of the AFMC Corporate Board responsible to review the approved*

portfolio of technology projects and issue top-level guidance for conducting the next cycle of technology strategic planning.[10]

Phase 4: Program Execution - Approved programs are executed by the AFMC centers. Each technology is reviewed by product center engineering for validation prior to technology transition to support a customer's weapon system or infrastructure requirement. Validation includes maturity criteria for affordability, performance, and sustainability. The Technology Transition and Transfer strategy greatly impacts this phase by recommending a different approach in executing technology demonstrations that includes low cost *incremental demonstrations* for technology maturation prior to executing more expensive integrated *flight or advanced environmental ground demonstrations* on strategically planned schedules. For example, the existing process for advanced development programs consists of various levels of laboratory and flight demonstrations with no guide of technology maturation for the manufacturing process development nor requirements to move from one level of demonstration to another. The proposed strategy requires all technologies for advanced development to be matured first through incremental technology demonstrations. If further manufacturing process and product maturation is required then the technology may move to an integrated flight or advanced ground demonstration.

4.1 Steering Committee Guidelines

The Panel proposed the following six operating guidelines to address the previously identified hurdles. These guidelines support the Packard Commission principles and the view of Mr. Les Aspin, former Secretary of Defense, on the acquisition reform to include: *more use of demonstrators & prototypes; emphasis on dual-use technologies; preference for commercial products and purchasing practices; simplification of acquisition procedures.*[11] These guidelines also support the goals of the Defense Reinvestment/Conversion Act of 1992 which *promote economic growth while ensuring the ability to serve future defense needs.*[12]

1. ***Advocate a philosophy (first principle) that encourages risk taking when payoff warrants and promotes <u>joint</u> risk management for government and industry. Change the paradigm "afraid of failure."*** Historically, the transition of technologies from 6.3A advanced development programs to operational systems has involved very

expensive risk reduction Demonstration/Validation (Dem/Val) and Engineering Manufacturing Development (EMD) phases. The reduced defense budget environment will no longer support this approach. Therefore, greater emphasis on risk reduction must be taken in the earlier phases of technology development. This approach requires improved risk management and sharing of both product and process data and methodology in 6.2 and 6.3A research between government, universities, and industry. These three sectors need to be partners in the development of technology to meet the warfighters needs. A joint Risk Management methodology that incorporates risk identification, assessment and screening, along with risk reduction and risk monitoring will ensure that potential risks for all design features, manufacturing processes, and supportability issues will be addressed during technology development.

2. ***Promote the use of commercial standards, practices, regulations, and innovative contracting approaches in demonstration programs where appropriate, to reduce cost and provide opportunities for commercial applications.*** Technology demonstrations should have less contractual requirements and be time phased similar to the commercial market, and include investment in manufacturing process technology development. In order to have a number of these demonstrations they need to be low cost contracts with an optimum number of deliverables, minimum oversight and increased partnership (IPPD team approach). *DoD needs to acquire as many of its products and services as possible through the use of commercial practices and to reduce the cost of conducting each acquisition.*[13] The MIMIC chip/module development provides an excellent example of low cost technology demonstrations to mature dual-use technology that has application to both military (AMRAAM, LANTIRN, ALQ-135, F-22 (radar & EW), and F-15 & F-16 receivers) and commercial (cellular telephone, wireless communications, direct broadcast satellite, aviation, and security systems.). A Manufacturing Technology Transmit/Receive (T/R) module project will look at producing T/R modules for both military and commercial application in the same facility.

3. ***Require Integrated Product and Process Development (IPPD) partnerships involving industry, government agencies, universities, and user community.*** IPPD partnerships get participants involved from the beginning, encourages participation, and exploits the power of joint planning and execution which, in-turn, reduces duplication and misdirection. Closer ties with both the military and commercial user will facilitate

technology transition and transfer. Technology research and development needs to foster strong working relationships between government, universities, industry, and user community. *A stable, viable defense industrial base is vital to ensure a wartime surge capability as traditional defense plants and industries are reduced.*[14] Rapid technology validation and deployment will necessitate utilization of both military and commercial test sites. Implementation can readily be facilitated through an IPPD approach. The MIMIC program is composed of IPPD teams across industry and DoD services and emphasizes the process development for designing, packaging, testing, demonstrating and producing chips/modules affordably with dual-use application. The companies on the IPPD team have been historical competitors but discovered that by working together they could combine the talents of the best technical experts from each company. Written agreements to share proprietary data within the team encouraged participation by all its members. Another example of company partnership is the recent agreement between IBM and Apple.

> *While each company maintains its separate competitive business integrity, programs are underway to ensure compatibility of system architecture, next-generation software interfaces and protocols and, in some cases, hardware. Apple and IBM have come together for one reason; each believes it is to its benefit to do so.*[15]

4. ***Encourage the development of both manufacturing process and product technologies in 6.2 and 6.3A research.*** Laboratory engineers, their product centers customers, and industry must change their mind set from a predominant focus on performance to a balanced approach where the potential cost impact of performance is fully considered. Improved cost and risk estimation methodologies, tools and databases must be developed that supports the focus of affordability. S&T exit criteria should be established between the laboratories and their customers to measure the maturity level of technology developed for transition to weapon systems. Technology development should focus all the factors which drive costs, for example, producibility, reliability, maintainability, supportability and environmental considerations along with performance. Concurrent development of both manufacturing process and product technology should begin at the 6.2 exploratory development. At this level of research, model shop processes can be used to prove manufacturing feasibility of a particular component. Product validation using modeling and "production-like" manufacturing floor processes needs to be accomplished at the 6.3A advanced development level. By addressing manufacturing process

development early during the product development, designs can be made robust and critical process variabilities can be controlled to affordably acquire the product. However, this approach requires industry and government laboratories to acquire and maintain the necessary resources in both personnel and facilities in order to perform this level of comprehensive research.

5. ***Encourage the use of joint company R&D partnerships to share tool and technology development so more effort can be dedicated to solving problems while minimizing the duplication of effort.*** In a reduced budget climate, more efficient use of resources for standard research tool development is required so more emphasis can be placed on product and manufacturing process development. It is important to shift the paradigm of independent company R&D to sharing R&D between companies while competing at the application and production level. An example of sharing R&D can be found in the NASP materials and structures program. The NASP MASAP faced major challenges in the area of materials characterization. A materials consortium was formed with 5 aerospace associate contractors managed by a government joint program office. The consortium focused on producible processes with lower costs, a smaller and less costly vehicle design, and the establishment of an advanced material supplier base. Both current and completed IR&D were shared by all team members to establish a current technology database. This database was use to determine an effective technology development plan while minimizing duplication of effort between companies. Each company knew its role including the products to be delivered for the program.

6. ***Promote the use of commercial applications as a way to mature technology for future military applications.*** Defense budget reductions have and will continue to reduce the number of military technology flight demonstrations. Commercial ground, flight, and advanced environmental ground demonstrations may be a viable alternative to mature technology. Commercial flight demonstrations may not deal with all the unique military issues but important systems integration issues could be evaluated. The differences in technology development for commercial application versus military application requires in-depth investigation to determine how to best combine and take advantage of both applications where feasible. The NASP program provides an excellent example of deriving technologies that can be further matured using commercial applications. *Economic benefits of the NASP program will outweigh the program costs to date of approximately $1.5 billion. According to an independent study conducted by Princeton Economic Research, Inc., Princeton , N.J., NASP derived technologies, over the*

next 10 to 15 years, could pump upwards of $26 billion, in product sales and life-cycle cost savings, into many current and emerging industries.[16] The maturation of these NASP derived technologies through commercial applications will eventually impact how these technologies could be used for future military applications.

4.2 Process and Product Development Research

Air Force laboratory planners would use the initiatives identified by the Steering Committees with weapon system and infrastructure technology development needs from the Technology Master Process to formulate research and development technology base plans for the establishment and execution of basic research, exploratory development, and advanced technology development programs. Exploratory development efforts should pursue high risk, high-payoff options that include an initial level of manufacturing process modeling and development. Advanced technology development programs should be risk reducing critical experiments that demonstrate technical feasibility of both product and manufacturing process at the component level in a laboratory or prototype factory environment. An important product from these research efforts is lessons-learned information and a database for future use. An information database or library to archive this valuable information and make it available for government, industry, and university researchers would help focus resources and reduce duplication.

4.3 Process Modeling

Advanced modeling capabilities are required to assess system performance from "cradle to grave." Manufacturing system performance, product behavior and performance, and acquisition & operation costs are critical parameters to be assessed.

> *New defense acquisition strategies require development of the capability to prove the manufacturing and affordability of new weapon systems prior to risky and expensive acquisitions. Concerns about the loss of manufacturing capability in an era of "near zero" production, place increased emphasis on the development of approaches to transition technology more rapidly, while, at the same time, ways need to be found to reduce the time and effort required to engineer and produce products. The new strategies also rely heavily upon the concept of low volume, co-mingled production of DoD and civilian products in "dual-use" facilities.*[17]

Development, validation, and utilization of models to assess technologies during process and product development research, including technology demonstrations, is critical to reducing cost and risk.

> *The cost of validation will be significant, but this step is required to ensure that a true representation of the manufacturing process exists. Validation should be part of an Advanced Technology Demonstration's (ATD's) exit criteria. Test and validation using real weapon system applications will provide confidence that product and manufacturing process simulations can be used in lieu of repetitive prototype design, fabrication, and test.*[18]

4.4 Incremental Technology Demonstrations

Promising technologies from exploratory development should be demonstrated with the objective of meeting the users' defined needs through risk reducing "proof of application" incremental technology demonstrations. These demonstrations should have less contractual requirements and be time phased similar to the commercial market, and include investment in manufacturing process technology development. In order to have a number of these demonstrations they need to be low cost contracts with an optimum number of deliverables, minimum oversight and increased partnership (IPPD team approach). Also, they must mature some technologies sufficiently to allow for dual-use applications. The purpose of these demonstrations are to provide continuous opportunities for technology maturation through laboratory simulations, ground demos, and pilot factory demonstrations performed by government, industry, and academia. They would be conducted at the component or higher level in an application oriented test environment where potential users could participate or observe. These incremental technology demonstrations should have funding and milestone continuity to provide technology readiness, including product development and manufacturing process scale-up and factory implementation, for transition and transfer to dual-use applications.

4.5 Synergistic Technology Demonstrations

These technology demonstrations would provide further manufacturing process and product maturation and risk reduction through commercial and/or military demonstrations by government and industry. Demonstrations will use an Integrated Product and Process

Development approach with identified transition and transfer opportunities. A matrix of technology demonstrations ranging from advanced environmental ground demonstrations to highly integrated flight demonstrations should encourage synergism between aircraft, avionics, and propulsion technology. The matrix should be defined by the level of technology maturation that would be achieved. The IHPTET program management process provides an excellent example of using a matrix of demonstrations that includes sequential time-phased engine demonstrators for nearer term technology transitions, concurrent development of far term technologies, and risk reduction of ongoing and future programs. IPPD partnerships must be used to plan flight demonstrations that are strategically scheduled to further mature emerging incremental technology products. Lessons learned from the NASP program have proven that achieving a flight demonstration is not the only goal for doing these more costly programs. Well planned and executed flight demonstration programs can yield numerous payoffs, in both manufacturing process and product technologies for dual-use applications, along the way to the goal.

4.6 Commercial and/or Military Applications

Technology should be matured through the market that provides the greatest "pull" for both product technologies and manufacturing processes. This technology can then be transferred to other markets when potential application exists. Industry must take the lead in deciding which technologies have the greatest potential for transfer between military and commercial markets. This technology transfer will require cooperative ventures between companies and between companies and government laboratories. Industry consortiums may be required to identify potential technologies to meet both commercial and military user needs. *Industry must counter the financial community's focus on short-term profits and adopt a long-term strategy to technology and product development.*[19] The government laboratories must support technology transfer through better advertisement of laboratory sponsored research. This is critical for the promotion of dual-use technology development. Better awareness of laboratory research programs could be accomplished through industry and university participation in the Technical Planning Integrated Product Teams (TPIPTs) of the AFMC Technology Master Process.

5.0 Summary

The Technology Transition and Transfer Strategy supports DDR&E's Science & Technology vision: *Develop and transition superior technology to enable affordable, decisive military capability and to enhance economic security.*[20] A key element of our strategy is the establishment of three high-level steering committees in the technical disciplines of avionics, propulsion, and airframes, to establish national goals to maintain U.S. aerospace leadership. The successful implementation of this strategy into the current development and transition of technology for weapon systems requires not only the endorsement and leadership by DoD, industry, and universities but the commitment by all participants to meet the challenge of long-term planning for a high technology industry that is critical to both economic growth and defense of our country.

6.0 References

1. Article, "Re-Engineering C3I Operations," Emmett Paige Jr., Defense '93, Issue 6, Report on the Bottom-Up Review, October 1993.
2. William Clinton's Technology Policy, NSS/Georgetown, 21 September 1992.
3. Fiscal Year 1993 Title IV Appropriations for TRP Programs, March 1993.
4. "White Paper on Technology Master Process", BGen Richard Paul, HQ AFMC/ST, 9 July 1993.
5. Report, "1987 Summer Study on Technology Base Management," Defense Science Board, December 1987.
6. Briefing, "Risk Management," Brett Roberton, Pratt & Whitney, October 1993.
7. Presentation, AFMC CEO Day, "Lean Aircraft Initiative Overview," Lt Gen Fain, ASC.
8. Affordability in Science and Technology (S&T) Development, Wright Laboratory Affordability Team, WPAFB, OH, Draft Copy - 26 July 1993.
9. Project Manager's Notebook, Defense Systems Management College, October 1985, Introduction to Acquisition Management, Air Force Institute of Technology, April 1992.
10. Commander's Policy, "Technology Master Process," AFMCR 500-24, 1 November 1993.
11. John Deutch's View on Acquisition, Under Secretary of Defense, NSS/Georgetown.
12. Defense Conversion, Reinvestment, and Transition Act of 1992.

13, 14. Article, "Re-Engineering C3I Operations," Emmett Paige Jr., Defense '93, Issue 6, Report on the Bottom-Up Review, October 1993.

15. Article, "Acquisition Reform: Making it a Reality," C. Preston, Acquisition Review Quarterly, Winter 1994.
16. Article, "Benefits of the Journey," AFMC Leading Edge, September 1993.
17. Paper, "Virtual Manufacturing: A Methodology for Manufacturing in a Computer," An Air Force MANTECH Perspective, October 1993.
18. Report, "Engineering in the Manufacturing Process," Defense Science Board Task Force Report, March 1993.
19. Article, "Tech Transfer Leadership Falls to Industry, Not Labs," Aviation Week & Space Technology, 6 September 1993.
20. Briefing, "Defense Science and Technology Strategy," Dr. Anita Jones, DDR&E, 24 March 1994.

General References

21. Report, "A Study of Technology Transfer Within The Air Force Systems Command," Cormier and Salvucci, Sloan School of Management, MIT, June 1986.
22. Program Information Package, "Defense Technology Conversion, Reinvestment, and Transition Assistance," ARPA, 10 March 1993.
23. Information Package, "Air Combat Command IRAD Review Process," HQ ACC/DRS, August 1993.
24. Draft Background Paper, "Development Technology Needs Generation and S&T Project Definition," M. Snead, AFMC/STPS, 8 Feb 1994.